ENERGY EFFICIENT CLUSTERING AND ROUTING TECHNIQUES IN HIERARCHICAL WIRELESS SENSOR NETWORKS

SYNOPSIS

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1. INTRODUCTION

WSN is considered as one of the important area of research and became very popular advancement in Wireless Communication [WC] [1]. Wireless Sensor Networks [WSN] consists of large number of tiny sensor nodes that have capability to sense the surrounding region, perform computations and communicate wirelessly with their neighboring nodes and to the base station at low cost. Sensor nodes are small, light in weight and are portable. These sensor nodes are randomly dispersed in large surface area and gather the information through the sensing unit, process them and transport it to the destination called sink [1]. Every sensor nodes consists of three subsystems namely communication, sensing and processing to perform task assigned to them properly [1]. A major goal of WSN is to monitor the specified area, to detect and to record events and to measure the desired parameters. Characteristics of WSN include self organization, concurrent processing, low cost, restricted energy resources and small radio range [2]. Once the transmission takes place, energy gets depleted and it's not possible to replace sensor nodes and the network becomes non-functional even if single node dies. One of the major challenges faced by WSN is to balance between network lifetime and energy consumption as both are indirectly proportional to each other. Proper clustering and routing techniques can be adopted to overcome this challenge. Clustering involves grouping of sensor nodes into clusters and elect cluster heads for each clusters so as to avoid long distance communication to the base station, optimizes the resource consumption and supports better quality of service. Routing is needed for data transfer between the sensor nodes and the base station to establish proper communication at short distance. Still research has been going on to overcome these challenges.

This research with the help of proper optimization technique, the balance between energy consumption and network life. But Quality of Service (QoS) and time delay is also a crucial factor in WSN. Thus, this research focus on developing a network with less energy consumption, increased network life, better Quality of Service and less delay.

2. LITERATURE SURVEY

With rapid development in technology for cluster formation and route selection; certain algorithms have revealed fast growth in recent years. It is due to certain characteristic features of some algorithm and some hybrid algorithms are also developed with additional features. The need for creating proper path rises day by day.

2.1 CLUSTERING

Clustering is process of grouping sensor nodes based on certain parameters and selecting the optimal Cluster Heads (CH). Each sensor nodes sends the collected data to Base Station (BS) either directly or indirectly.

Selim Bayrakli et al. [3] explain about the Genetic Algorithm (GA) for expanding the life time of network and the simulation results states that the GA based optimization algorithm increases network lifetime by selecting appropriate number of Cluster Heads and its locations

Gaurav Kumar et al. [4] focus on boosting LEACH algorithm by adopting certain features of Particle Swarm Optimization (PSO) algorithm and is named as ESO-LEACH. The results reveal that the network life span using ESO-LEACH doubles when compared with LEACH.

S.Famila et al. [5] improves the feature of Artificial Bee Colony (ABC) optimization by adopting Grenade Explosion and Cauchy operator to select optimal cluster head to enhance network lifetime and to reduce energy consumption in sensor nodes.

Marwa Sharawi et al. [6] applies Grey Wolf Optimization (GWO) algorithm for cluster head selection. Results are compared with Leach which defines that the new algorithm outperforms Leach.

P.T.Karthick et al. [7] applies Krill Herd [KH] algorithm to get optimal cluster head selection which is inspired from food searching and communication behavior of krill herd.

Madhusudhanan et al. [8] modifies Fire Fly (FF) algorithm by allowing the node with higher fitness to attracts the one with less fitness for selecting proper cluster heads and to increase the efficiency of energy and also to reduce packet loss ratio.

ROUTING

Routing is the process of finding shortest path between two nodes for increasing the energy efficiency and network lifespan.

G.R.Annusha Kumar et al. [9] considers fitness as a major factor which includes certain parameters like transition distance, average minimum distance, energy left in a node, energy dissipated during transmission, cluster distance for optimizing energy exhaustion in the network using GA.

Gaurav Sudhir Deshmukh et al. [10] proposes GA based system which creates energy efficient clustering and selects best route with better energy efficiency and network life time. This paper also explains about mobile sink for improving energy efficiency.

Padmalaya Nayak et al. [11] evaluates the fitness based on two parameters namely energy and distance to find shortest distance between two nodes using GA.

Santosh Kumar Verma et al. [12] selects alternate route if the current route fails using Binary Particle Swarm Optimization (BPSO) algorithm.

Djamila Mechta et al. [13] improves network life using Fish Swarm Optimization Algorithm (FSOA) inspired from food searching behavior of fish. Praveen Lalwani et al. [14] describes the way in which Harmony Search Algorithm (HSA) is used to solve clustering and routing issues in WSN by utilizing its memory.

3. PROBLEM FORMULATION

Primary challenges identified behind implementing suitable cluster based routing protocol are as follows:

- Each node may prone to unanticipated failure.
- High speed energy exhaustion takes place in sensor nodes as it is responsible for data communication, gathering and aggregation.
- Based on application, nodes must be capable of moving anywhere in sensor field.
- WSN should have capability to work in dynamic topology.
- Communication failure.
- Various types of sensor nodes deployed must work in cooperative manner in WSN.
- Each sensor should be utilized in such a way that produces maximum performance with less energy.

4. OBJECTIVES OF RESEARCH

The following are the objectives of the research:

- To improve network lifespan
- To reduce high speed energy exhaustion
- To improve latency and QoS
- To avoid data loss

5. PROPOSED METHODOLOGY

A step-by-step methodology of research plan is given below:

Step 1: Initially number of nodes, number of data packets are generated and the initial energy and the time duration are set.

Step 2: Clustering is done based on Genetic Algorithm based clustering.

Step 3: Results of the clustering are compared with the existing method and analyzed in the form of graph.

Step 4: Routing is carried out based on On Demand Node Behavior (ODNB) protocol.

Step 5: Results of the routing are compared with the existing method and analyzed in the form of graph.

Step 6: Security is performed using Multi criteria based Secured Routing Protocol (MSRP).

Step 7: Results of the security are compared with the existing method and analyzed in the form of graph.

5.1 CLUSTERING

GA based energy optimization algorithm overcomes finds a suitable CH, which leads to cluster formation using feedback information.

OVERALL FLOW OF PROPOSED ALGORITHM

Overall flow of the proposed work is represented in the figure 1

Step 1: The initial population is generated randomly.

Step 2: Fitness is calculated based on energy, distance and the number of alive nodes.

i. The parent node is selected based on a probabilistic method.
ii. A single point cross over is applied over it.
iii. A mutation operator is applied if needed.

Step 3: The new population is updated based on the generation of new offspring.

Step 4: Depending on the best fit chromosome, CH selection and cluster formation is carried out.

Step 5: End.

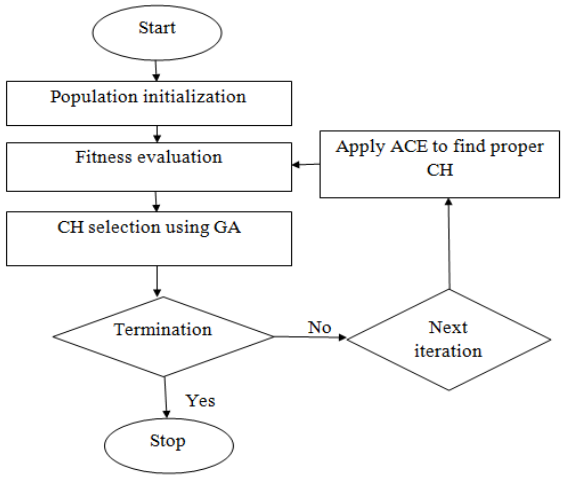

Figure 1: Overall Flow of the proposed work

Transmitter and receiver energy is calculated using the equations 1 and 2 and the equation 3 represents the energy required for acknowledgement of packet exchange.

$$E_{Tr(m,d)} = E_{ele} * m + \varphi_{amp} * m * d^2 \quad (1)$$

$$E_{Re} = E_{ele} * m \quad (2)$$

$$E_{ACK} = \tau_{ACK} (E_{Tre}(m,d) - E_{Re}) \quad (3)$$

where $\tau_{ACK} = \eta_{ACK} / n$ is the ratio between length of packet to acknowledgement of packet.

Total energy required is calculated using the equation 4,

$$\text{Total energy} = E_{total} = E_{Tr\,(m,d)} + E_{Re} - E_{ACK} \quad (4)$$

where, E_{ele} and φ_{amp} are constants and m represents number of bits transmitted or received. d denotes the distance between transmitting and receiving antenna and E_{ACK} is energy consumption for acknowledgement packet exchange.

- **Fitness calculation:**

Fitness is calculated based on residual energy, distance and number of alive nodes. The equation 5 represents the fitness function.

$$F(CH) = \{E*\sin(mA)\}/\{ E_n + D_n \} \quad (5)$$

E_n = energy of node

D_n = distance between two nodes

mA = number of alive nodes

E = Sum of energies of all alive nodes

Based on the fitness value, the fittest chromosome selects the CH for current iteration. The required number of CHs is selected based on energy and once the CH is selected, member nodes join their respective clusters based on distance. Nodes collect data and send it to their respective CHs and the CH gathers the data and fuses it and finally transmits to the base station.

5.1.1 RESULTS AND DISCUSSION

Work is done using the simulation tool MATLAB 2020a. Nodes are randomly distributed in a square space $(N*N)m^2$ as shown in figure 2. Simulation is performed using 100 nodes in an area of $(100*100)m^2$.

Table 1 Simulation Parameters

Parameter	**Value**
Number of nodes	100
Field Area	$(100*100)m^2$
Optimal number of clusters	10
Number of iteration	1400
Cross over percentage	0.5
Mutation rate	0.01

Sensor nodes are scattered in the target area and form 10 clusters each consisting of one CH. After each iteration, CH is changed and a new cluster is formed. Simulation parameters are discussed in Table 1.

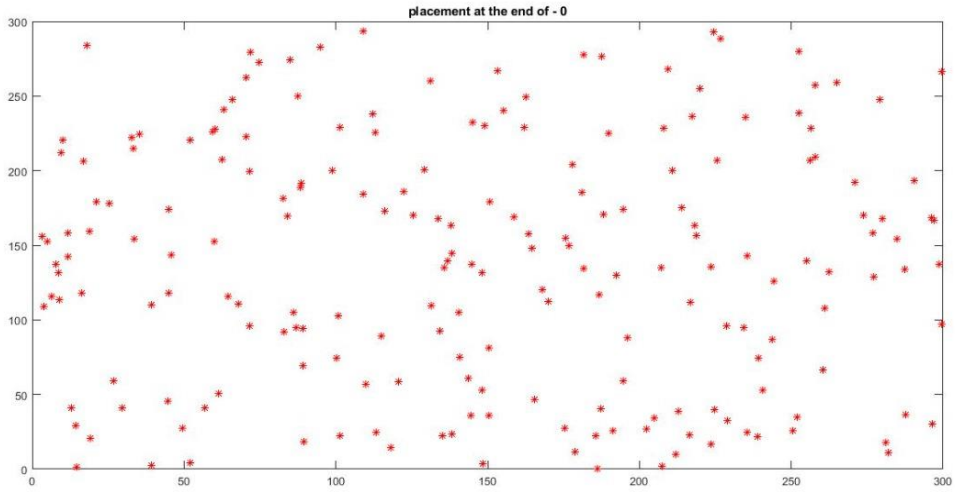

Figure 2: Random distributions of sensor nodes in 100*100

Table 2: Comparison of residual energy with the LEACH protocol and the proposed work

ITERATIONS	Residual Energy (J)	
	LEACH	Proposed work (Genetic Algorithm based clustering)
200	44	45
400	33	35
600	25	27
800	15	20
1000	9	12
1200	1	6

Table 2 compares the residual energy of the proposed system and the existing system. Initial energy is 50J. In 200 iterations, the residual energy using the LEACH protocol is 44J whereas the residual energy using the Genetic Algorithm is 45J. It gradually reduces and at iteration 1200, the residual energy using the LEACH protocol is 1J whereas the residual energy using the Genetic Algorithm is 6J which is around 12% from the initial energy and in case of LEACH protocol, the residual energy is around 2%.

Table 3 Comparison of Network lifetime (Number of alive nodes)

ITERATIONS	NETWORK LIFE (Number of alive nodes)	
	LEACH	Proposed work (Genetic Algorithm based clustering)
0	100	100
200	100	100

400	100	100
600	100	100
800	99	100
1000	89	100
1200	70	99
1400	53	83

Table 3 compares the network lifetime based on the number of alive nodes with the LEACH protocol and Genetic Algorithm. Initial numbers of nodes are 100. Finally, at the end of 1400 iteration, 83% of nodes are alive in using the Genetic Algorithm whereas only 53% of nodes are alive in case of LEACH protocol.

Table 4 Comparison of intra cluster throughput

ITERATIONS	**INTRA CLUSTER THROUGHPUT (Number of packets delivered to the CH)**	
	LEACH	**Proposed work (Genetic Algorithm based clustering)**
0	2000	2000
100	1500	1500
200	1100	1200
400	1000	1100
600	900	1000
800	700	900
1000	600	700
1200	400	500
1400	100	300

Table 4 compares the intra-cluster throughput. Initially 2000 packets are transmitted and at the end of 1400 iteration, 300 data packets are delivered to the CH while using the Genetic Algorithm whereas while using LEACH protocol only 100 packets reaches the CH. As results, more than 10% of packets reach the destination when compared the proposed work with the existing method.

Table 5 Comparison of intra cluster throughput

ITERATIONS	**INTER CLUSTER THROUGHPUT (Number of packets delivered to the base station)**	
	LEACH	**Proposed work (Genetic Algorithm based clustering)**
0	2000	2000
100	1500	1500
200	1500	1500

400	1400	1500
600	1300	1400
800	1000	1200
1000	600	700
1200	400	500
1400	100	350

Table 5 compares the inter-cluster throughput. Initially 2000 packets are transmitted and at the end of 1400 iteration, 350 data packets are delivered to the CH while using the Genetic Algorithm whereas while using LEACH protocol only 100 packets reaches the CH. At the end of 1400 iteration, 17.5% of total packets are transmitted using the Genetic Algorithm.

5.2 ROUTING

Routing is carried out based on On Demand Node Behavior Protocol (ONDB). On Demand Routing (ODR) is performed to monitor the nodes and to analyze the defects. Detection of node behavior will monitor the transmission pathway. Node behavior is analyzed during route creation and data routing to detect malicious nodes. Main task is to detect the malicious nodes and the selfish nodes that breaks the overall communication.

The following steps are followed once the source and destination have been identified.

1. On Demand Routing (ODR)
2. Status allocation
3. Construction of graph
4. Processing of the graph
5. Node behavioral analysis
6. Path query

On Demand Routing (ODR)

Cost of path construction is one of the disadvantages in discovering the shortest path. Large networks are unstable and the network topology changes frequently which causes the breakage. If the position of the node is changed, the node has to be updated which consumes time and energy. This problem is solved by Thourup-Zwick approach. Before transmitting the data to neighbor, it verifies the local cache initially and if the two nodes are connected earlier, then the request packet is sent to sink for acknowledgement. The path with shortest distance is used for transmission of data packets.

Status allocation

Sink communicates directly with the other nodes which is responsible for source initiated on-demand routing protocol by gathering basic information from the neighbor. The information contains current status and node location. In this algorithm, the covering node receives the status report from its neighbor. The status report from each node contains the parameters for message transmission and is denoted as $v_i = <E_i, PRR_i, L_i, C_i>$ where E_i and PRR_i represents the residual

energy and packet reception ratio. L_i and C_i represent the load status and connection status. Once the information is collected, the information is forwarded to the covering node by sink.

Graph construction and processing:

The overall information is sent to the sink node, once the status allocation is completed. Graph construction is done by the weighted graph. When the distance between the nodes is greater than the communication range, then the transmission distance becomes infinity. Fixed weights are used to avoid the infinity range. Preprocessing of graph is essential for transmitting the message to other nodes efficiently.

Node behavioral analysis:

Node behavior is analyzed during data routing and route creation. Behavior of intermediate nodes including the source node and destination node is required for identifying and detecting the malicious nodes. Performance of WSN is based on trustworthiness of nodes. Based on the functionality of intermediate nodes, the source and destination node perform well in the network. Every time On Demand Node Behavior (ODNB) determines the operation of individual nodes to complete a single communication operation. Change in node behavior is due to power loss, mis-communication, reconfiguring the properties of node, change of power sources and irregularity in the work assignments. This results in data loss and causes malicious activities in the network.

Classification of nodes

The nodes are classified into various categories such as

$W=\int T(\text{prob}\ [R,U,M,S])$

where

- R = Reliable node
- U = Un reliable node
- M = Malicious node
- S = Selfish node

Reliable node (R): This type of node will deliver the control information and data packets while performing routing and find the exact path for efficient routing.

Unreliable node (U): In this type of node, network will be unstable as a result of “out of communication range”, ”high congestion” and ”frequent link failure”, etc.

Malicious node (M): This node provides suspicious activities, interrupting routing by periodically propagating “denial of service”,” packet forwarding delays”, ”route manipulation” and so on.

Selfish node (S): During routing, resource is unreliable and do not respond to the control message in order to conserve resources

Path Query

Once the weighted graph is processed, sink will get ready for sending response to the covering node based on path query.

5.2.1 Results and Discussion

The ODNB protocol is simulated using the Network Simulator-2 and the performance is verified in terms of Quality-of-service. Table 6 describes the network parameters in the software environment.

Table 6 Simulation Parameters

PARAMETERS	VALUES
Network area	(100 *100)m^2
Execution time	10s,20s,….,50s
Mobility	Yes
Number of nodes	100
Packet size	256 bytes

Table 7 Packet Delivery Ratio w.r.to malicious nodes

Number of malicious nodes	Packets Delivery Ratio (PDR) (%)		
	TMS	RTA	PROPOSED (ODNB)
10	92	93	99
20	85	90	98
30	62	75	95
40	55	70	90
50	30	49	75

Packet Delivery Ratio is the number of packets received successfully at the destination. The performance is evaluated by simulating a different number of malicious nodes and calculating QoS values. From the table 7 it is clear that the average packet delivery ratio using the proposed work is 92.2% higher than the other existing methods.

Table 8Packets Dropping w.r.to malicious nodes

Number of malicious nodes	Number of packets dropped		
	TMS	**RTA**	**PROPOSED(ODNB)**
10	198	180	175
20	300	275	250
30	399	300	275
40	500	400	300
50	600	590	390

The number of packets dropped is calculated by subtracting the number of packets received successfully at the sink from the number of packets transmitted from the source node. 1000 data packets are transmitted initially. As the number of malicious nodes increases, number of packets dropped also increases. In table 8, when number of malicious nodes is 10, only 17.5% of packets are dropped and when 50 malicious nodes are considered, 39% of packets are dropped which very much less than other two existing methods.

Table 9 Delay w.r.to malicious nodes

Number of malicious nodes	DELAY(ms)		
	TMS	**RTA**	**PROPOSED**
10	400	400	200
20	510	490	300
30	600	550	500
40	900	800	600
50	1050	950	700

From table 9, it is noticed that the delay in the proposed model is much less than that of the other methods. Initial time period is 1500ms. When 50 malicious nodes are considered, the delay is almost 47% which is less than other two existing methods.

Table 10 Energy consumption w.r.to malicious nodes

Number of malicious nodes	ENERGY CONSUMPTION(mJ)		
	TMS	**RTA**	**PROPOSED**
10	38	21	20
20	60	56	30
30	79	79	42
40	81	90	46
50	120	140	62

According to the table 10, the proposed method consumes less energy than other existing methods. Initial energy is 200mJ. When number of malicious nodes are 50, 31% of energy is consumed which is less than other two existing methods.

5.3 SECURITY

Depending on network architecture, uncountable number of applications performs its functions. As the number of devices and data transmission increases, possibilities of malicious activities also increase. Every node has the ability to interact with the server and other nodes. Every time, the control layer is responsible for performing additional processing and stops all network processes if malicious node behavior is suspected. Several methods have been put forward to increase security and energy efficiency. In accordance with the current system, if malicious nodes are engaged in the network, it consumes more energy and produces more unwanted data, thus increasing computational time and complexity. Clustering, CH selection and data routing are classified according to Multi Criteria based Decision Making. Generally, malicious nodes can create multiple malicious nodes in the network and generate many unwanted data and creates time complexity. MSRP detects and isolates the malicious nodes and reduces unwanted communication and reduces the data loss.

Multi Criteria based Decision Making Model: The functionalities of multi-criteria-based decision making model is depicted in figure 3. CH is selected based on multiple conditions.

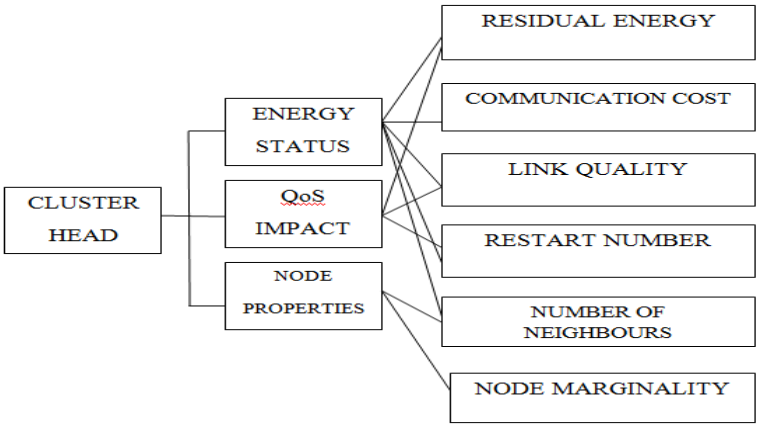

Figure 3 Multi-criteria-based Decision making for selecting the CH

The following steps will explain various conditions by making decisions for selecting the CH.

Condition 1: Initially check if the available nodes in the current iteration are clustered. If all nodes are clustered, then switch to condition 2; else, if the location of the node is verified in the cluster for clustering the available nodes, then the weight ($weight_i$) of the node is evaluated by updating the neighboring node. Then the weight of each node is shared with the neighboring node in the same cluster. Then, switch to condition 2.

Condition 2: Check, weight of node i is greater than the other nodes in the cluster. If $weight_i > t(n)$, then the condition is satisfied and the message is sent to the selected node, then switched to condition 3. Otherwise, the system waits to get a message from the CH_i.Condition 3 takes place, after identifying these parameters.

Condition 3: If $T > T_{round}$, then the cluster head receives the message from each member node, and data aggregation is done for selecting the next CH. If condition 3 is not true**,** then T is reset and once again processed from condition2. This process ends if the optimal CH is selected.

The proposed multi criteria model is used in the network during route creation. From the source to the destination, all the possible nodes are taken into account and the best route for data transmission is chosen. This routing protocol is simulated, and the results are verified.

5.3.1 Results and Discussion

Network Simulator-2 is used to simulate the MSRP to verify the performance of the network in terms of Quality-of-Service. Table 11 describes the parameters of the network in the software environment.

Table 11 simulation Parameters

PARAMETERS	VALUES
Network area	(100*100)m^2
Execution time	10s,20s,…,50s
Mobility	Yes
Number of nodes	100
Packet size	256 bytes

Table 12 Network lifetime w.r.to malicious nodes

Number of malicious nodes	NETWORK LIFETIME (sec)			
	(Proposed Work)MSRP	ESMR	AODV	TSRF
10	980	970	890	855
20	950	940	885	850
30	930	920	880	845
40	920	900	870	840
50	910	890	850	830

To assess the network lifespan, the proposed MSRP is compared with the Ad-hoc On-Demand Distance Vector Routing (AODV) Protocol, Trust-aware Secure Routing Framework (TSRF) and Energy-efficient and Secure Mobile node Re-authentication scheme (ESMR) is shown in table 12. Initial time period is 1000s. When number of malicious nodes is 10, the life

time last for almost 980 sec. when number of malicious nodes is 10, the life time last for almost 910 sec which is very much higher than other two methods. The MSRP selects the path which is most dependable and energy efficient among other routing lines.

Table 13 Network throughput w.r.to malicious nodes

Number of malicious nodes	NETWORK throughput (kbps)			
	Proposed Work (MSRP)	ESMR	AODV	TSRF
10	140	130	120	117
20	140	131	123	119
30	140	132	125	120
40	140	134	126	121
50	140	135	127	122

In order to access the network throughput with different malicious nodes, the proposed MSRP protocol is compared with other existing protocols and is shown in table 13. From the results, it is evident that the proposed MSRP outperforms other current protocols in terms of network throughput. The proposed model increases network performance by 36% when compared with other protocols. It is ideal for handling energy efficient systems.

Table 14 Energy consumption w.r.to malicious nodes

Number of malicious nodes	Residual Energy (J)			
	Proposed Work (MSRP)	ESMR	AODV	TSRF
10	1.5	1.3	1.1	1
20	1.4	1.2	1	0.9
30	1.2	1.1	0.8	0.7
40	1.1	0.9	0.6	0.5
50	0.9	0.7	0.5	0.3

Initial energy is 2J. Table 14 compares the proposed work with the current procedures in terms of energy usage. The proposed method enhances its performance by 34% when compared with other methods. More energy is utilized in the current procedure because of significant route breakage and because it also sends data along with the malicious nodes. When integrating with energy efficient and dependable nodes, the proposed method outperforms current methods.

Table 15 Delay w.r.to malicious nodes

Number of malicious nodes	DELAY (sec)			
	Proposed Work (MSRP)	ESMR	AODV	TSRF
10	500	600	700	750
20	400	400	550	650
30	300	300	450	450
40	200	200	300	300
50	100	100	200	200

Table 15 demonstrates the reduced delay in the proposed work when compared to the current protocols in the presence of different malicious nodes. The proposed work performs almost 29% perform better than other protocols. Other protocols lack the ability to find the shortest routing pathway. As a result, the proposed model successfully selects the shortest routing path.

6. Conclusion

The primary focus of this research work is to create a balance between network life time and the energy efficiency and to find a secured energy efficient clustered based routing techniques in Wireless Sensor Network. The comparative study of different optimization methods is done with the aim of finding a best protocol to perform secured cluster based routing in a hierarchical wireless sensor network. Clustering is performed using the Genetic Algorithm based approach. Genetic Algorithm is used for proper cluster formation and Cluster Head selection. In the proposed method feedback will be received after each iteration. Best shortest path to transmit the data from source to destination is done using On Demand Node Behavior (ODNB) algorithm. Here, the shortest path is found based on the demand and behavior of the node to detect the malicious nodes that disrupt the path and creates long distance transmission. Secured data path is needed to avoid data loss during the transmission. In this research Multi-criteria based Secured Routing Protocol (MSRP) is used to transmit the data in a secured way. The results of each method are tabulated and compared with the existing methods.

7. ORGANIZATION OF RESEARCH

The thesis is organized as follows:

Chapter 1 describes about the Wireless Sensor Networks (WSN), its challenges and applications and also about the methods adopted to overcome those challenges. **Chapter 2** reviews the literature related to this research work. **Chapter 3** describes the clustering and method used to select the cluster formation and proper cluster head selection. **Chapter 4** details

about the routing technique used to find shortest path. **Chapter 5** discuss about the proper security required for the network.

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PUBLICATION DETAILS:

JOURNALS

1. Y.P.Makimaa, Dr.R.Sudarmani, "Survey on Energy Optimization Techniques for Clustering and Routing in Applications of Wireless Sensor Networks" *Solid State Technology, Vol : 63 Issue:6,pp.2145321462,Dec2020.*

2. Y.P.Makimaa, Dr. R. Sudarmani "Incorporating Node Behavioural Analysis with On-Demand Secured Routing of Improving the Efficiency of Wireless Sensor Networks Applications"*Indian Journal of Computer Science and Engineering-volume 12 issue 6 pp1674-1686Nov-2021* .

3. Y.P.Makimaa,Dr. R. Sudarmani, "Genetic Algorithm Based Energy Efficient Cluster Head Selection and Cluster Formation and Establishment for Hierarchical Wireless Sensor Networks", *International Journal of Intelligence Systems and Applications in Engineering, Vol. 10, Issue 04, pp. 173 – 178. ISSN: 2147-6799.*

4. Makimaa, Sudarmani.R, Vanithamani. R, "Different Energy Harvesting, Energy Saving Techniques to Improve Battery Energy of Wireless Sensor Networks-A Review", *Stochastic Modeling & Applications Vol. 26, No. 3 , pp.72-83, (January - June, Special Issue 2022 Part - 7).*

5. Dr. R.Sudarmani, Y.P.Makimaa, "Remote Continuous Health Monitoring System using Wearable Sensor Networks and IoT",*International Journal of Intelligent Systems and Applications in Engineering, volume 10 issue 4 pp 192-194.*

Conferences

1. Y.P.Makimaa, Dr.R.Sudarmani," Energy Efficient Cluster Formation and Cluster Head selection using Genetic Algorithm (GA) and Algorithm for Cluster Establishment (ACE)", *International Virtual Conference on Advances in communication, machine learning embedded with Internet of Things, conducted by department of Electronics and Communication Engineering, Kongu Engineering College".*
2. Y.P.Makimaa and Dr.R.Sudarmani," Survey on Secured Routing Protocol in Wireless Sensor Networks", *International Conferences on Advances in Science, Engineering and Technology conducted by Cheran College of Engineering.*